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SOME LABORATORY EXPERIMENTS INVOLVING REAL CHEMICAL PROBLEMS

Many pupils look upon chemistry as an occult science. It is associated in their minds with curiously shaped apparatus, explosive mixtures, evil smells, a maze of formulae, and most uninteresting lessons in a text book entitled "Elementary Chemistry." Such pupils have failed completely to make connection between their class work and experiments on the one hand, and the world of applied chemistry beyond the laboratory. True, certain so-called applications of chemistry may have been pointed out, usually as a kind of afterthought following an especially bitter dose of chemical theory. The pupil's feeble spark of interest has been too completely destroyed to be rekindled to any consuming flame by such a method. So he fails to see in what he is called upon to learn, anything which will help him solve his own individual problems.

Several reasons for this condition may be pointed out. Teachers as a class are loaded down with a burden of subject-matter. So many pages of text must be covered, a corresponding number of laboratory experiments performed, and accompanying notebooks written up. Under this burden the teacher tends to emphasize completeness rather than suggestive methods of presentation. To the teacher, with his thorough knowledge of the subject, the natural order of presentation seems to be: first, theory, text-book assignments and recitations; second, experiments to show how the theory works or to illustrate the topics studied; third, applications, if any. Is this order adapted to the immature mind of the pupil? Chemistry, from the standpoint of pure science, may demand such a presentation, but does not the science of teaching chemistry to growing young people demand the reverse order of presentation?

Facts persist in memory only when fixed by extraordinary conditions, or when a keen live interest which perceives their usefulness is appealed to. The successful chemistry teacher is the one who can most completely supply his pupils with a large variety of such keen interests. It is the duty of the teacher to arouse the interest in his pupil, and it is the function of the laboratory work, recitation, and text, to provide the food and stimulus under which this interest may thrive.

In the laboratory the pupil should find himself purposefully working out the solution of real problems which he feels to be worth while because they are his own. Once the pupil feels this, he is not only willing but eager to repeat his work until satisfactory results are obtained and tasks which seemed rigorous are accomplished with enthusiasm.

If this be true, the method of presentation which will best arouse the interest should be the teacher's first concern. Hence the starting point should be made with the discussion of values and applications in relation to the facts of every-day experience in the home, school, and immediate surroundings of the pupil. Here is a motive which will not fail at the first difficulty, which will help the pupil over the hard places with a minimum of effort on the teacher's part. On all sides, the chemistry teacher is surrounded with excellent material for experiments which will deal with real problems possessing this powerful appeal.

No more direct method of arousing interest and securing enthusiasm can be found than asking the pupil himself to secure the materials for experiments, bringing them from home, from the grocery store, or any other source that he chooses. This chance to be of real assistance to the teacher gives him the dignity of a co-worker, and puts the work at the outset upon a higher plane than that of a formal set task.

Early in the year members of the class are asked to investigate the kitchen, pantry shelves, medicine cabinet, and prepare a list of chemicals in daily use. This list is kept and, as the course proceeds, the various items are checked off after more intensive study. This list is easily made, and often helps the pupil in connecting the facts he is learning with every-day experience, and thus it aids in arousing his interest.

The following experiments have been tried in this school and found successful in no small degree in supplying and developing interest and a strong motive for pursuing topics further than the next examination. No claim for originality is made. Many teachers are using similar experiments and with like inspiring results. The number of conventional textbook experiments is still too great, but it is diminishing and will diminish as fast as the other kind may be devised.

TESTING THE HARDNESS OF SPRING AND MINERAL WATERS

This experiment is performed after pupils have learned simple tests for the salts most commonly found in ground waters. Each pupil is asked to secure a suitable sample, water from a spring, artesian well, or a bottle of mineral water from the drug-store. A great variety of samples, from widely different sources, always results. At least one pupil may be asked to test the water used in the school boilers. The laboratory directions follow in full:

(*a*) Weigh a clean, dry, porcelain evaporating-dish. Weigh into it 100 grams of sample. Place on the steam-bath and evaporate to dryness. If necessary, finish the evaporation in an air-bath at a temperature of 120° C. Again weigh the dish and its contents. The weight of the residue is the amount of total dissolved solids.

(*b*) While evaporation is going on, to separate portions of the water, apply tests for chlorides, sulphates, nitrates, carbonates. Perform any other tests which the instructor may suggest, to suit individual problems. Record the tests as *very positive, positive, trace,* or *negative.*

(*c*) Fill a burette with a soap solution made by diluting ordinary liquid soap (used in the school) with three times its volume of distilled water. Place 100 c. c. of the water you are testing in an Erlenmeyer flask. Add a few drops of the soap solution and shake. Continue adding the soap solution, a few drops at a time, and shaking until precipitation ceases and suds form. The number of c. c. of soap solution used indicates, comparatively, the hardness of the water.

(*d*) Dissolve the residue in the porcelain dish in a little dilute hydrochloric acid. Note whether a gas (carbon dioxide) is liberated. This will check the test for carbonate. Using a clean platinum wire and the hydrochloric acid solution, examine the spectrum of the residue. What elements are indicated by this test?

(*e*) What reasons can you see for softening the water to be used for laundry purposes and in steam boilers? What method can you suggest for softening the water which you have analyzed? Write equations for any reactions that have taken place in this testing.

DETERMINATION OF THE PERCENTAGE OF AMMONIA IN HOUSEHOLD AMMONIA WATER

This experiment accompanies the study of acids, bases, and salts, and serves thoroughly to fix this important topic. It has to do with real material of importance in daily use, and the reaction of the class towards this experiment is far different from that towards the analyses of test solutions made up in the laboratory to practice upon.

Bring from home or purchase at your grocery store, a sample of commercial household ammonia. This sample should be not less than one-half pint in volume and should be brought in a tightly stoppered bottle. It is also necessary that it be part of a fresh bottle, not a portion of one which has stood any length of time unstoppered. Using the burettes and cochineal as an indicator, determine by the method of titration the number of c. c. of 10 per cent hydrochloric acid required to neutralize 25 c. c. of sample. The exact amount of HCl in 1 c. c. of the standard acid solution has been determined and is given on the board. Write the equation and calculate the exact amount of NH_3 in the 25 c. c. of sample used. Express the result in per cent.

Tabulate your result with those obtained by other members of the class. Note the brand, manufacturer, cost per quart, as well as its value expressed in per cent of ammonia. Determine the cost per quart reduced to a 1 per cent solution, by dividing the cost per quart by the per cent of ammonia found. This enables you to compare the value of various brands directly, that giving the lowest figure being the most economical to buy. Record the results of your titrations and give your calculations in full.

Report the results of your analysis to your family and to your grocer, with recommendations as to the best brands to purchase.

DETERMINATION OF THE PERCENTAGE OF ACETIC ACID IN VINEGAR

The preceding experiment on the analysis of ammonia water aroused such interest that the class wanted more work of the same character, and they were given the following experiment on the analysis of vinegar:

Bring from home or purchase at your grocery store, a sample of vinegar; preferably of the variety that you use at home. Fill a clean, dry burette with a portion of the sample. Fill a second burette with a solution of sodium hydroxide containing exactly 50 grams of NaOH to the liter. Draw off exactly 25 c. c. of the vinegar into an Erlenmeyer flask. Add 200 c. c. of distilled water, seven or eight drops of a 5 per cent solution of phenophthalein, and titrate exactly with the sodium hydroxide, until the pink color characteristic of this indicator in alkaline solution is just reached. Repeat the titration until agreeing results are obtained.

One c. c. of the sodium hydroxide solution contains .05 grams NaOH. Write the equation for the neutralization of acetic acid by sodium hydroxide. On the basis of this equation, calculate the amount of acetic acid $HC_2H_3O_2$, corresponding to 1 c. c. of the sodium hydroxide solution. Find the number of grams of acetic acid in 25 c. c. of the vinegar analyzed. With a hydrometer, determine the specific gravity of your vinegar. Now find the weight of 25 c. c. of sample. From the weight of 25 c. c. of vinegar and the weight of acetic acid contained in it, calculate the percentage of acetic acid. Measure the volume of the original container and find the cost per quart. Record these facts, along with the brand, manufacturer, and variety of the vinegar analyzed. Record, also, the amount of sodium hydroxide used in titration, the specific gravity, the percentage of acetic acid stated on the label, if given, and give your calculations in full.

An idea of the character of the results obtained by the class in these two experiments may be gained from the following tables:

ANALYSES OF AMMONIA

BRAND	PER CENT OF NH_3	COST PER QT.	COST PER QT. PER 1%
Elston	1.20	10	8.33
Elston	1.11	10	9.01
Kenwood	2.41	13.3	5.52
Standard	2.13	14.3	6.71
Standard	2.16	14.3	6.62
Excelsior	.54	7.2	13.33
Household	7.5	34.2	4.56
F. F. F. F.	.48	10	20.83
Red Riding Hood	3.10	12.5	4.03
King	.90	10	11.11
Druggist's	9.66	40	4.14

ANALYSES OF VINEGAR

BRAND	PER CENT ACETIC ACID	PER CENT BY MFR.	COST PER QT.	VARIETY
Matchless	3.96	..	10c	Cider
Matchless	4.08	..	10c	Cider
King Cereal	3.95	..	10c	Cider
Webb	4.16	4	10c	Cider
Cross & Blackwell	5.45	5.5	35c	Malt
Stock	4.3	..	5c	Distilled
Red Riding Hood	4.3	..	10c	Cider
Red Jacket	4.70	..	10c	Cider
None Such	4.08	4	15c	Cider
Trojan	3.91	4	10c	Distilled
Aeneid	2.5	..	5c	Cider fermented at home

Results of the class work, when tabulated on the board, showed at once great variations in the value of ammonia water and very little variation in the percentage of acetic acid in vinegar. The reasons for this produced a lively discussion of standards of purity as controlled by law in the one case and uncontrolled in the other.

THE DETECTION OF SULPHUR DIOXIDE IN FOOD PRODUCTS

In much the same way a great variety of food products were examined by the class to see whether sulphur dioxide or a sulphite had been used as a preserving agent. The list of products examined included dried and preserved fruits, canned vegetables, meats, and several varieties of cooked and uncooked sausage.

(*a*) Weigh out 50 grams of sample, place in a large flask, barely cover with distilled water, and add 15 grams of granulated zinc and sufficient pure hydrochloric acid to produce rapid evolution of hydrogen. The hydrochloric acid used should first be tested for its freedom from sulphates, as these would interfere with the test. Over the mouth of the flask place a filter paper which has been moistened with a solution of lead acetate. Any sulphur dioxide which may be present will be reduced by the nascent hydrogen and hydrogen sulphide formed. This will be indicated by a brown stain on the filter paper, where the hydrogen sulphide will have deposited lead sulphide black in color. The formation of such a brown stain, then, proves the presence of some sulphite or sulphur dioxide in the material examined. Record the test as *negative, trace,* or *positive.*

(*b*) Place another 50-gram portion of sample in a flask, cover with distilled water as before, and add 25 c. c. of hydrogen peroxide. Shake occasionally for a period of ten minutes, and filter. Test the filtrate by adding barium chloride and 5 c. c. of strong hydrochloric acid. A white precipitate proves the presence of a sulphate which has been formed by the oxidation of any sulphurous acid or sulphite present in the food by the hydrogen peroxide. Record this test, also, as *negative, trace,* or *positive.*

(*c*) Record, not only your own results, but also the materials tested and the results obtained by the other members of your section. Write equations for the action of zinc and hydrochloric acid; sulphur dioxide and nascent hydrogen; hydrogen sulphide and lead acetate; sulphurous acid and hydrogen peroxide; barium chloride and sulphuric acid.

The discussion resulting from this experiment concerning food preservatives had real experience as a background and left a permanent impression upon nearly every pupil.

Space does not permit of a full description of other experiments in which the pupil provides his own material. A partial list includes the following:

THE ANALYSIS OF A SILVER COIN OR SCRAP PIECE OF STERLING SILVER

The silver is recovered from solution in nitric acid by treatment with copper. The cement silver is washed free from copper salts, dried, and weighed. Per cent of silver found is calculated. Per cent of copper obtained by difference. The refined silver is cast into a button, mounted as a stick-pin, and in some cases etched with designs or class numerals.

THE QUALITATIVE EXAMINATION OF BAKING POWDERS

Directions for a qualitative examination of baking powders are found in several laboratory manuals. The real problem lies in having the pupils determine by the use of these tests which brand is the most desirable. The tests are not the end of the experiment, but the means to make a real analysis. The motive in this kind of testing is real and impelling.

THE PREPARATION OF ALCOHOL BY FERMENTATION OF BROWN SUGAR WITH YEAST

The alcohol is distilled off, dried over quicklime, and redistilled. This experiment is especially valuable, as it gives the pupil a real experiment involving fractional distillation. He has a pure product as the result of his work.

THE ANALYSIS OF LIQUID SOAP USED IN THE SCHOOL

This experiment grew out of a complaint about the quality of the liquid soap used throughout the school. Samples of this soap, and of that furnished by other firms, were tested by various members of the class. This material required a real analysis. Samples of the various brands were titrated against standard acid to find per cent of free alkali and against a 5 per cent solution of calcium chloride to determine softening power.

Not only is there an unlimited number of such experiments suitable for class use, if we set about devising them, but in addition pupils should be encouraged to bring in any material which they want to investigate, to test it, and analyze it if possible. The chemistry laboratory should be used at other times than the assigned periods. Such individual problems as the following are suggestive:

TESTING TEA FOR DYES, SUCH AS PRUSSIAN BLUE

TESTING CANNED CHERRIES FOR DYES AND BENZALDEHYDE

TESTING POWDERED SUGAR FOR FLOUR OR STARCH

TESTING CANDIES FOR COAL-TAR DYES, GLUCOSE, AND FLOUR

A pupil in the seventh grade became interested in testing some cheap candy bought near the school. The chemistry department was called upon to help. The results of the testing were given in a morning exercise. As a result a rule forbidding the buying of cheap candy from this source was adopted and lived up to by the entire school.

TESTING THE ROOMS AND LABORATORIES OF THE SCHOOL FOR THE AMOUNT OF CARBON DIOXIDE IN THE AIR

These tests were applied to typical class-rooms throughout the school by a member of the chemistry class, at the request of the physics class, who were engaged in studying the ventilation system. The results of this testing are included in the article on *Heating and Ventilation—a Problem in Applied Physics.*